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Tree architecture

A valuable (old) new tool

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Tree architecture

A valuable new tool to inform (veteran) tree management

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What is tree architecture?

All arborists can probably recognise tree species from afar, let's say driving by in a car. And they can even do this in winter time when there is no foliage. But only a few can really explain how they know for sure they are looking at an oak and not a lime. When asked, people usually refer to 'branching pattern' or 'habit', but altogether it is more of a gut feeling, acquired through years of tree work. Tree architecture is the branch of science that puts words and concepts to this gut feeling, explaining why a tree looks how it looks. Unfortunately for arborists in the UK, most tree architecture literature is published in French because the main scientists in the field are French or Canadian.

To explain the branching pattern and habit of an individual tree, we usually refer to soil, light, water, wind and similar external factors. Of course, these have a great impact on a tree's development. But we often forget that each tree species also has an internal blueprint of how it ideally would develop. According to Claude Edelin, one of the pioneers of tree architecture, the architecture of every individual tree is the expression of an equilibrium between this internal blueprint and the external constraints exerted by the environment. This article focuses on that blueprint, ignoring external factors such as stress and the tree's response, and most importantly considers how knowledge about tree architecture can inform management.

Although scientists and artists have been looking into plant architecture, including tree architecture, for centuries, it only really developed into an actual branch of science in the 1970s as a spin-off from plant morphology. Plant architecture tries to identify fixed and repetitive phenomena in plant structures, valid for all individuals of the same species or even valid for multiple species. This is done by observing and schematising many individuals of the same species, in all life stages, to try to identify the 'building plan' of that species.

Architectural models

Based on the observation of architectural characteristics, trees can be subdivided into groups with similar characteristics (based on type of branching, type of extension growth, branch orientation, flowering position). One would think that there is a virtually endless number of combinations possible, but research has shown that all trees in the world are confined to only 23 architectural models, each of which represents a fixed set of architectural characteristics and thus a similar building plan.

Tree species from temperate regions of Europe typically span only about eight architectural models. Other models are mainly seen in subtropical and tropical tree species. This approach leads to the somewhat surprising observation that very different tree species like sweet chestnut (*Castanea sativa*), Douglas fir (*Pseudotsuga menziesii*), common beech (*Fagus sylvatica*) and wild cherry (*Prunus avium*) all share the same architectural model. And on the other hand, closely related species like the common beech and its cousin the North-American beech (*F. grandifolia*) adhere to different architectural models. Knowing and understanding the architectural model of a tree species adds a degree of predictability to the development of individual trees: it helps an arborist understand why a tree grows in a specific way and what can be expected from it.

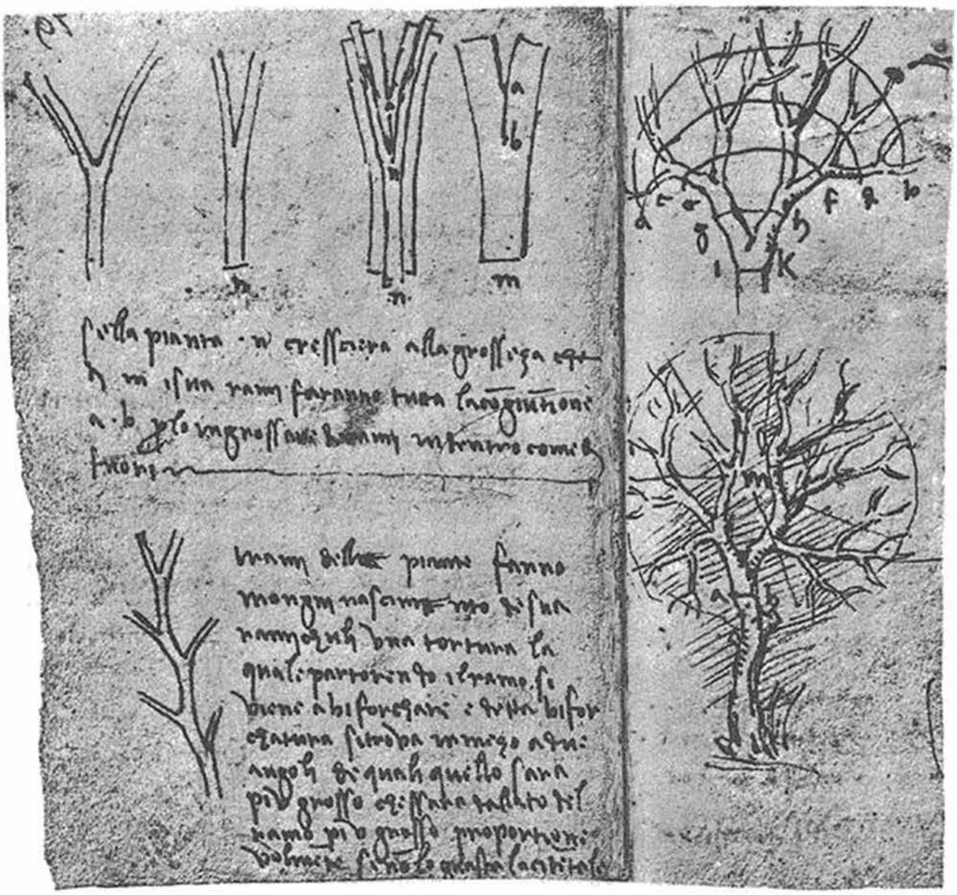

***Figure 1:** Leonardo da Vinci reflected on tree architecture in his sketchbooks.*

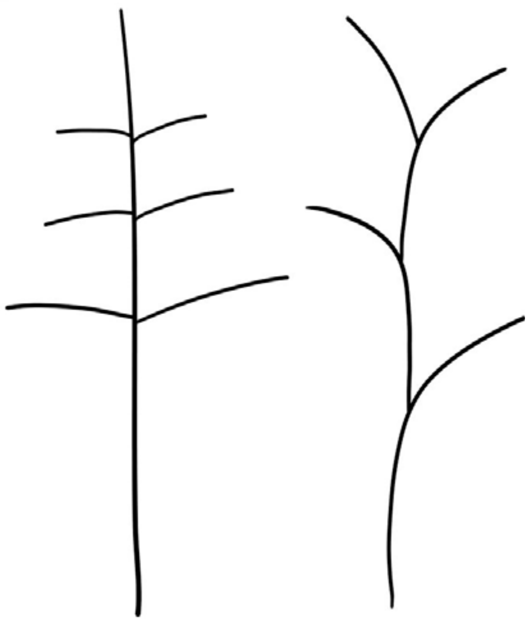

***Figure 2:** Compare the architectural model of a young beech (left) with that of a young elm (right). Although they look very different, both trees have strong hierarchy and apical dominance when young.*

Figure 3: The classic model of representing life stages of trees has great merits, but does not accurately describe reality. (© Helen Read/Sarah Wroot)

Development stages of trees

On top of its architectural model, a tree's architecture evolves according to its life stage. During recent years, many tree work professionals have become familiar with the concept of discerning different life stages of trees, as drawn in the image above. This model has great merit in making people aware of the fact that a tree's life does not end when dead branches appear in the upper canopy and that in fact the ancient life stage of a tree can be its longest.

However, while schematising tree development, some confusing generalisations have sneaked into this model. First of all, it is linear, with a start, a climax and an end, which does not concur with the fact that trees have the ability to continue living eternally. Secondly, this model implicitly links development stage and chronological age. This may be true for humans, but it is not true for trees: chronologically ancient trees can be in an earlier development stage than chronologically younger trees. And lastly and most importantly, this model combines a tree's development (the way it builds its stem and crown) with its reaction to stress or a change in its environment (e.g. natural crown retrenchment). Many ancient trees have actually gone through one or more cycles of natural crown retrenchment, but crown retrenchment in itself is not connected to a life stage; it can occur in any development stage. All of these problems can be tackled by looking at development stages from an architectural point of view.

An architectural approach to development stages

In order to properly look at development stages, we need to separate these from the reactions of the tree to external or internal stresses. So first, let's ignore stress and the tree's reaction to stress (usually involving epicormic growth) and look at theoretically perfect, stress-less development of a tree. In its first life stage, the young tree will be building its stem: a dominant axis aimed at rapidly gaining height. All branches are subordinate, the tree consists of one architectural unit with strong hierarchy. Depending on its architectural model, hierarchy in the young tree can be more or less obvious (see figure 2). Depending on external factors (e.g. competition for light), this first life stage and the subsequent stem length can be shorter, e.g. in open-grown trees, or longer, e.g. in woodland trees.

The tree enters its second life stage, reaching adulthood, when its apical dominance weakens and the stem reiterates for the first time: it forks into two or more ***equivalent*** parts (codominant stems/limbs) and the tree starts building its crown. After some time, a second reiteration wave (major fork) will occur on every codominant limb higher up in the crown, again doubling the number of codominant stems or limbs. Several waves of reiteration later (usually around five) the tree crown has more or less reached its maximal size: the tree is at the pinnacle of its abilities, a mature tree. The major limbs continue to double into increasingly smaller forks, sustaining the crown, until the tree reaches senescence at about 10 waves of reiteration. In this life stage, the outer canopy consists of an accumulation of very small forks, making it look like a giant cauliflower. The sheer size of the structure the tree needs to maintain and the increasing hydraulic resistance in its sapwood and twigs will eventually lead to progressive dieback in the outer canopy: the tree enters senescence. If a tree did not have the ability to take side routes developing epicormic growth, senescence would be its final development stage as the crown continued to die back and eventually the tree would die.

But let's step back into the real world and readmit stress and reaction. No tree can develop its stem and crown over centuries without experiencing at least some form of stress. And that is where the side routes and variations to normal development pop up. Depending on the intensity and duration of the stress, a tree will exhibit changes in its branch architecture (impoverishment of its twig structure) or dieback in the upper crown. If the tree is resilient, it will eventually restore its primary crown by developing orthotropic epicormic shoots (from the Greek 'orthos' – straight and 'tropos' – direction) in the upper canopy: vigorous, upright shoots that mimic the architecture of a young tree. This would of course be the preferred option from the tree's point of view: a temporary dip and then back to normal.

If the tree for some reason is not able to restore its primary crown, it might develop a secondary crown. During this process of natural crown retrenchment, mainly plagiotropic epicormic shoots develop lower down on the limbs and on the stem (plagiotropic from the Greek 'plagios'– oblique and 'tropos'– direction), mimicking the architecture of a young branch. The tree is then aiming to reach a new physiological equilibrium, with a secondary crown closer to its roots.

In cases where stress and dieback mainly affect the upper part of the crown, the tree might continue only developing the lower part of its primary crown, without developing a new, secondary crown: the tree falls back to a lower position. In each of the former scenarios the new crown resumes its normal development, reiterating and thus forming consecutive major forks.

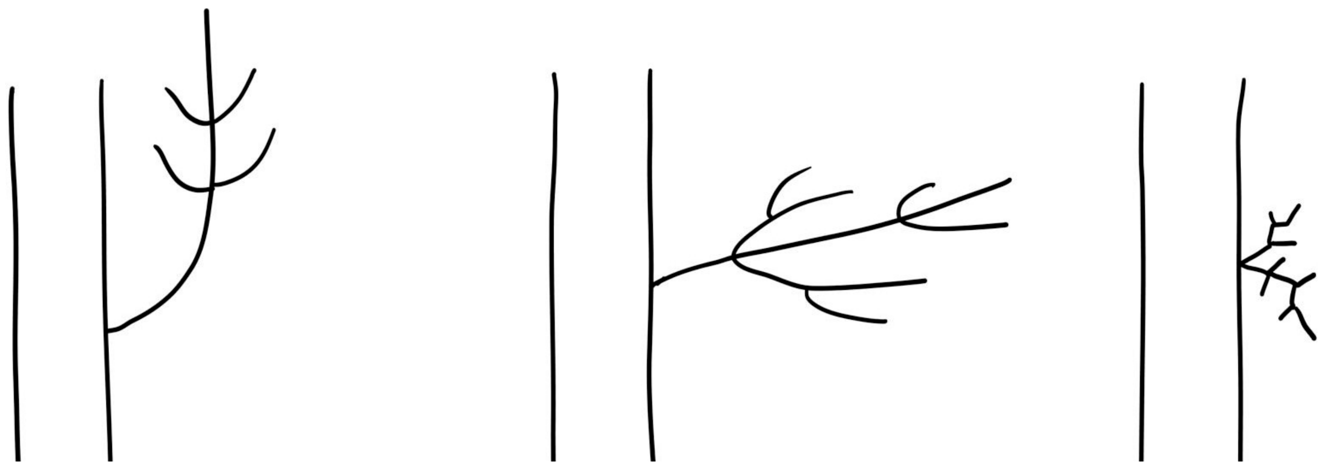

Figure 4: Different types of epicormic shoots point at the different reaction potential of the tree: orthotropic epicormic shoots (left) mimic the architecture of a young tree; plagiotropic epicormic shoots (middle) mimic the architecture of a young branch, ageotropic epicormic shoots (right) mimic the architecture of senescence.

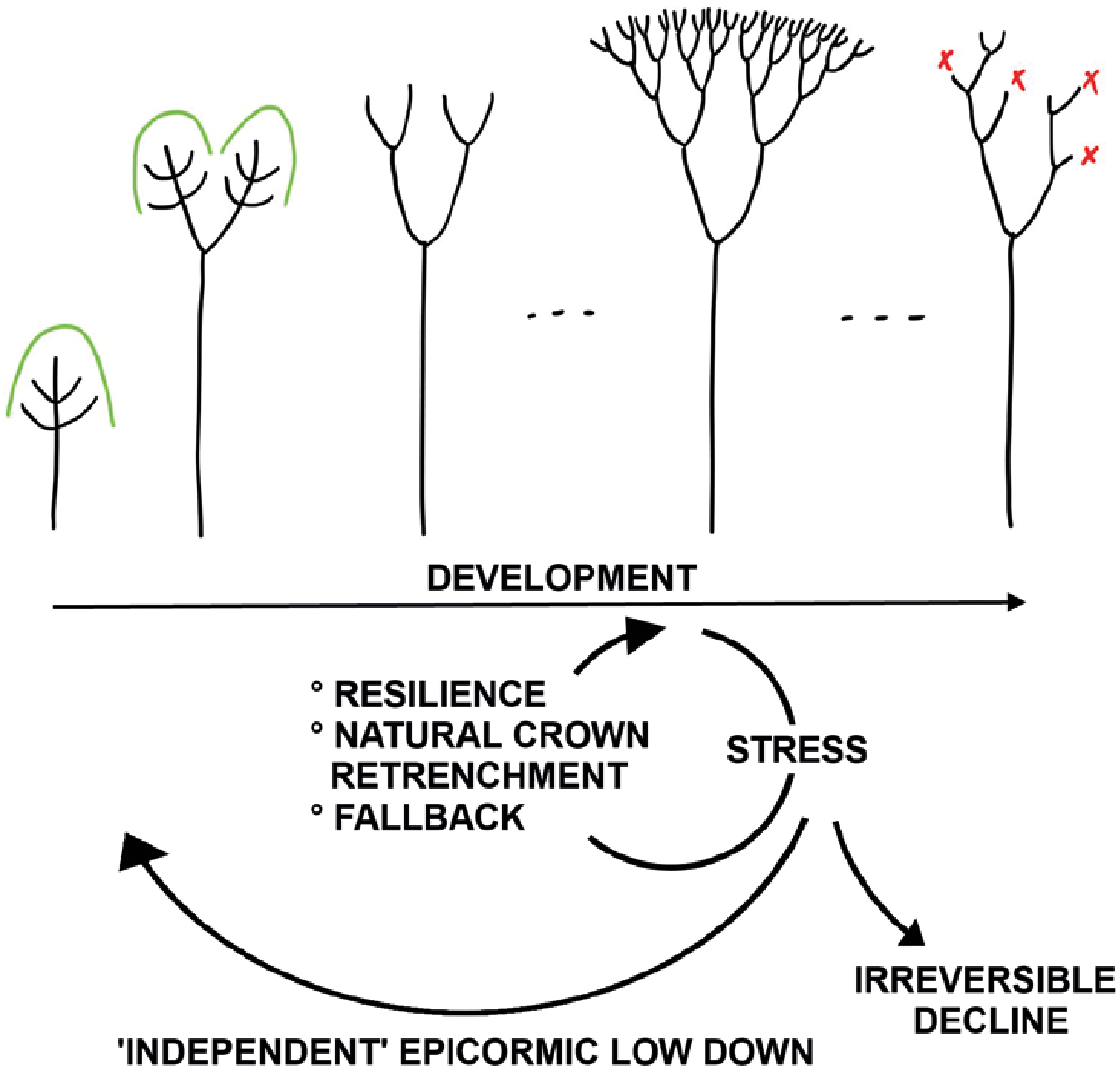

***Figure 5:** An architectural representation of tree development: a young tree to the left, exhibiting subsequent reiterations of the stem and reaching senescence after about 10 'waves of reiteration' (not shown here), followed by dieback of the crown and eventually a 'natural death.' Stress or environmental changes lead to the tree reacting, with several potential variations to normal development. If a tree cannot react adequately, it might get stuck in irreversible decline and eventually die 'prematurely'. (Adapted from Drénou)*

Worst-case scenario is that the tree does not regain good health, but can only rely on ageotropic epicormic shoots (from the Greek 'a'– without, 'geo'– earth and 'tropos' – direction). These small and gnarly epicormic shoots have the characteristics of old age and can barely sustain their parent branch, let alone help the tree recover from stress. Trees only exhibiting this kind of epicormic shoots are considered to be in irreversible decline. This does not necessarily imply they will die any time soon, but their chances of recovery are minimal.

A last scenario might be the development of one or more vigorous epicormic shoots low down on the stem base or the roots, which develop (and root) independently and start developing as any normal young tree would. Note that this model is not linear, but circular. Trees can consecutively experience several periods of stress or changes in their environment and react in different ways, depending on the type and duration of stress or change and the condition of the tree. In this model, trees can even 'reinvent' themselves and start all over again, as they would do in reality.

When trees reach advanced development stages, usually after surviving multiple stress/reaction or change/reaction events, they exhibit a very complex structure. In fact they can split up into several, semi-autonomous functional units, becoming a colony of trees rather than an individual tree. And in such a colony, some functional units may well be in a different life stage to others (including young trees) and also demand a different management.

Epicormic growth

As seen above, epicormic shoots play a key role in a tree's ability to react. So instead of ignoring it – or worse, pruning it away – arborists should take into account epicormic growth when managing trees. Epicormic growth enables a tree to react to stress, the alleviation of stress, changes in its environment, catastrophic events, etc.

The tree needs its epicormic growth to explore the side routes and deviations from its normal development which are essential for its longevity. But in order to evaluate what the epicormic growth is telling us and to inform management, we should be able to distinguish between the different types of epicormic growth set out on page 45: orthotropic, plagiotropic and ageotropic epicormic shoots, including their position in the crown.

***Figure 6:** Terminal bud of a senescent sycamore* (Acer pseudoplatanus): *the tree exhibits terminal flowering, leading to subsequent forking.*

Senescence versus decline

In managing veteran trees, a tipping point is reached when trees start exhibiting dieback in the canopy. Although they may look similar, it is important to be able to distinguish between senescence and decline. Senescence is a life stage and thus a normal and predictable part of the development of a tree. It cannot be reversed by management. Management can only prolong the senescent life stage and postpone further dieback. The typical branch architecture for a senescent tree is very gnarly, with short growth units and an accumulation of many small forks.

Decline, on the contrary, is a regression of the tree before it has reached its full development, as a result of stress. If you can find the primary reason for the decline, it might be reversed with the right management. For example, if a tree suffers from soil compaction, it might be possible to halt the decline and help the tree recover by stopping the compaction and improving the soil. The right management might restore the impoverished branch architecture back into the normal one for the tree's development stage, stimulate recovery

***Figure 7:** Twig architecture of senescent sycamore* (Acer pseudoplatanus): *a succession of small forks, very different from the architecture of a young sycamore. This architecture is related to the development stage of the tree, not to decline.*

Figure 8: *Lime tree* (Tilia × europaea) *planted in 1676–77 in front of Tongerlo Abbey, Belgium. Despite its old chronological age, the tree exhibits the architecture of early adulthood.*

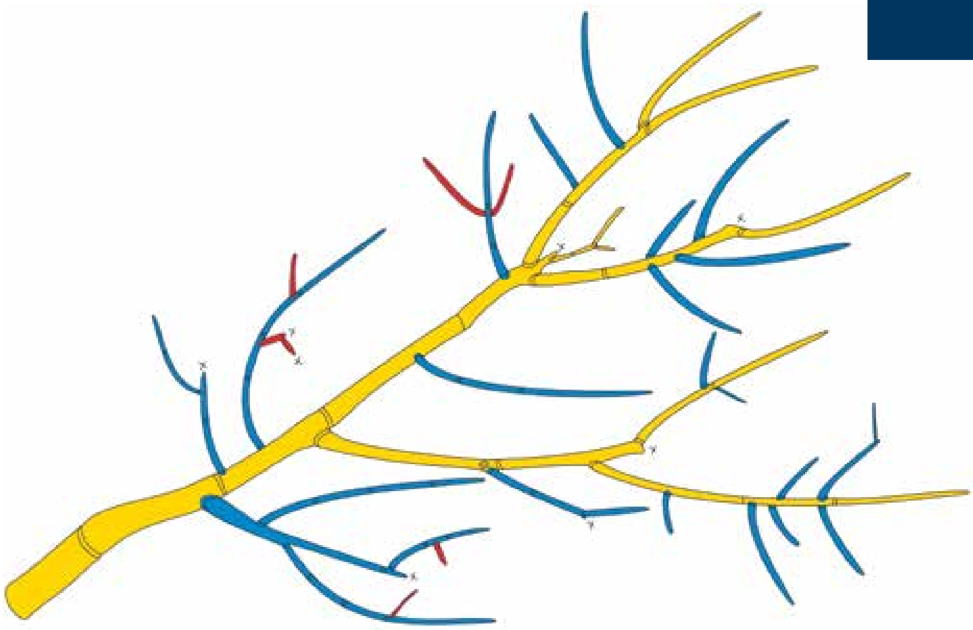

***Figure 9:** Schematised branch of an ancient oak in Lummen. This image allows us to analyse twig architecture, polycyclism, number of axe categories, etc. to support or nuance analysis on a macro scale.*

of the primary crown or stimulate the formation of a secondary crown.

Implications for management

In order to integrate an architectural analysis into management decisions and take into account all of the above, arborists must be able to evaluate a tree's (architectural) development stage, its condition (health) and resilience (capability to react) and its past and present reactions (old and new epicormic growth). Rather than just evaluating a tree's current status and its chronological age in years, it is essential to see the process every tree is in: its architecture reveals its past and in many cases also its future development and reaction potential.

As an example, let's look at a lime tree (*Tilia* × *europaea*), planted in winter 1676–77 in front of the Tongerlo Abbey in Belgium. Its high chronological age and biomechanical problems, associated with stem hollowing, point the arborist towards a classic staged reduction to mimic the natural crown retrenchment process. The architecture of the crown (probably secondary) on the other hand shows a tree in its early adulthood (two to three reiterations/major forks in the crown). When this tree receives the first of a planned series of reduction cuts, it will most probably react by producing vigorous and upright (orthotropic) epicormic shoots in the upper canopy, rather than start developing a secondary crown. By setting management goals focused on a tree's chronological age and biomechanical issues while ignoring its architecture and development stage, management can completely miss its objectives.

A similar architectural analysis can be done on a micro scale, analysing and sketching individual branches in order to evaluate branching patterns, polycyclism (multiple shoots in one growing season), number of axe categories, etc. (figure 9). This adds depth to the architectural analysis and can confirm or nuance what was seen on a macro scale.

Tree architecture is an essential tool to add to the arborist's toolbox in order to set correct management goals and to correctly evaluate past management. This article offers merely a glimpse through the veil of tree architecture, but hopefully it triggered a few 'Aha!' moments.

Tom Joye is a European Tree Technician and trainer at Inverde, the centre of expertise of the Flemish government's Forestry and Nature Conservation Agency. His main areas of expertise are veteran tree management and tree architecture.

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News update

ANCIENT TREE FORUM

The article on pages 44–49 has been provided by the Ancient Tree Forum, which champions the biological, cultural and heritage value of Britain's ancient and veteran trees.

Tree architecture two-day course

Want to learn about tree architecture and how it can be used to inform veteran tree management? The Ancient Tree Forum is hosting a two-day training course, delivered by Tom Joye, on Thursday 7 and Friday 9 November 2019.

This two-day course will focus on providing participants with sufficient information and experience to:

- Describe the genetic 'blueprint' that determines how the structure of a tree develops.
- Describe the difference between development stage and chronological age.
- Explain the circular life cycle of a tree.
- Identify the difference between orthotropic, plagiotropic and ageotropic epicormic growth and determine what this tells you about the reaction potential of the tree.
- Describe the difference between age-related senescence and decline due to external factors.
- Inform management of veteran trees based on the above.

The course costs £320 per person. Places can be booked via the ATF website: qww.ancienttreeforum.co.uk